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GRANT NUMBER: DAMD17-94-J-4067

TITLE: In Vivo Microscope MR Imaging of Breast Lesions

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REPORT DATE: October 1995

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

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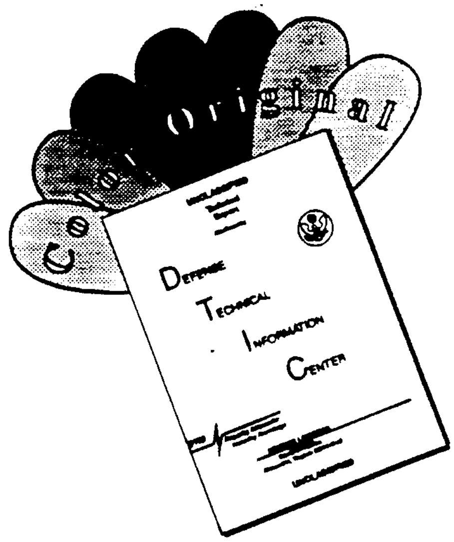

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	October 1995	Annual 1 Oct 94 - 30 Sep 95

4. TITLE AND SUBTITLE
In Vivo Microscope MR Imaging of Breast Lesions

5. FUNDING NUMBERS
DAMD17-94-J-4067

6. AUTHOR(S)
Elias A. Zerhouni, M.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Johns Hopkins University
Baltimore, Maryland 21205

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

An MR microscopy device was built for in vivo imaging of breast lesions as specified in our proposal. Small size RF reciever coils with diameters ranging from 3.2-7 cm were built and tested on phantoms. A frame to support the imaging coils was built that enables imaging in the prone and left or right decubitus positions. This frame was then tested on healthy volunteers and intitial clinical trials were begun. Three patients with suspicious lesions have been studied to date, with pathologic confirmation. To investigate the SNR performance, saline solution was imaged with various coil separations and diameters. The breast was compressed at the level of the suspected lesion between a pair of the surface coils positioned as close as possible to the lesion. The coils were connected to the scanner with the phased array method. Using the 3.2cm coils, the signal to noise ratio reached a level that enabled imaging with a resolution of 100μm and 3mm slice thickness.

14. SUBJECT TERMS
MR; High resolution imaging; breast lesion; breast cancer

15. NUMBER OF PAGES
11

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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Zerhouni, Elias A., P.I.
Grant No. DAMD17-94-J-4067

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1 INTRODUCTION

Imaging with low dose film-screen mammography is the currently recommended method of choice for the early detection of nonpalpable breast cancer in women over age 40.

Despite the high sensitivity of mammography, up to 9% of palpable cancers show no corresponding imaging abnormalities. Furthermore, with mammography, small cancers are often obscured by dense fibroglandular tissue. Another major limitation of mammography is its lack of specificity which has led to a marked increase in the number of surgical excisions for benign disease.

Mammography is a projection imaging technique with excellent in-plane resolution (on the order of 50 to 80 microns), but very low thru-plane resolution (the thickness of the breast). Overlapping structures are confusing, even for the most experienced observers. MRI can overcome the lack of thru-plane resolution with slice thicknesses in the range of 2 to 10mm but with poor in-plane resolution (600 to 1000 micron). At current levels of resolution, the fine details achievable with mammography cannot be matched by conventional MR studies[1-2]. In addition, it has been postulated that contrast enhancement patterns may be of diagnostic value but partial volume effects and the heterogeneous mixture of cancerous and normal tissue limits the analysis of specific lesions. The diagnostic assessment of breast lesions with MR would be improved with greater spatial and temporal resolution. We have developed a setup for in-vivo very high resolution MR of breast lesions using local RF coils permitting 2D and 3D assessment of lesion architecture at a resolution equal to or greater than 100x100x3000 microns.

2 METHOD

The desired image resolution can only be achieved with a significant improvement in the signal to noise ratio (SNR). This improvement can be obtained by combining small surface coils[3] with phased array methods. During the last year, we have built and tested a breast imaging system. The two-channel phased array RF receiver coil system is shown in Figures 1 and 2. The breast is compressed at the level of the suspected lesion between a pair of small size (3-7cm diameter) coils positioned as close as possible to the breast lesion. The position of the coils can be changed without moving the patient. The patient lies on the frame in a prone position (see Figure 4). This decreases possible motion artifacts. Alternatively, the compression plates can be detached from the frame and the breast can be compressed while the patient is in a more comfortable (left or right decubitus) position. We tested the coil and frame system on phantoms, volunteers and patients.

We built 3.2, 5, and 7cm diameter coil pairs using 2, 3, and 4 distributed capacitors, respectively. Each coil was independently tuned to 63.86 Mhz and matched to 50Ω using the circuit shown in Figure 3.

To analyze the effect of coupling between the coils on image quality, we imaged saline solutions with this set-up. Separation between coils varied from 3cm to 8cm with 1cm steps and the SNR of the phased array images were calculated along the axis of the coils and the values was normalized for an image resolution of 100μm.

3 EXPERIMENTS AND RESULTS

Tuning and matching of the coils were not affected when the separation of the coils was higher than twice the diameter of the coils. When the coil separation was approximately equal to the diameter of the coils, a 50% signal loss was observed (see Figure 5).

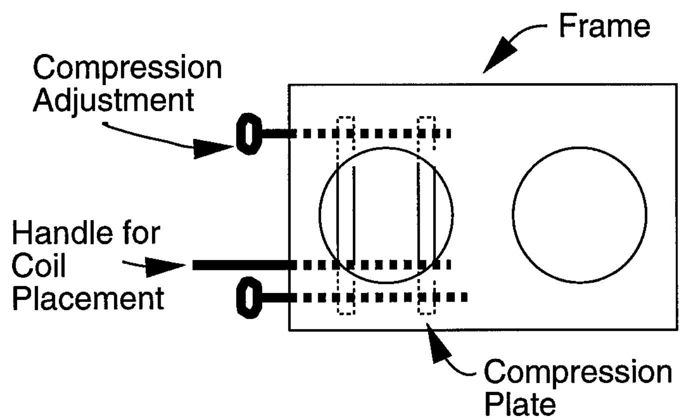

Figure 1: The top view of the breast MR microscopy system.

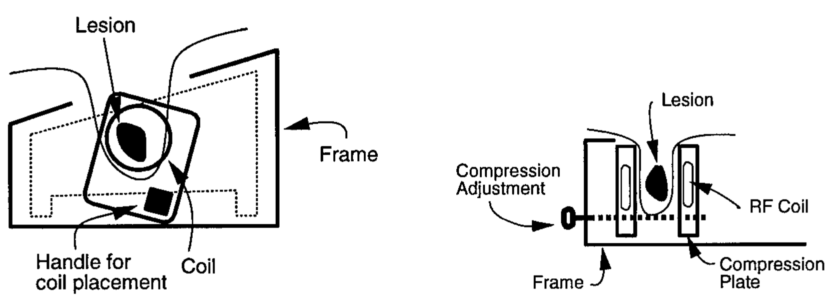

Figure 2: The cross-sectional views of the breast MR microscopy system.

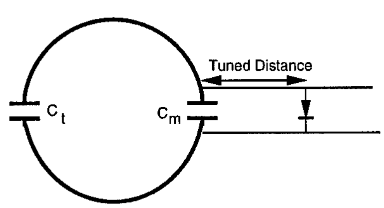

Figure 3: The circuit diagram for each of 5cm coils.

Two healthy volunteers and three patients were imaged by the new breast coil system on a GE Signa 5.2 scanner with 4-channel phased array and 3-axis EPI gradient upgrade. Using 7cm coils with a coil separation of 7cm, images of the lesion were obtained (see figure 6). The coronal images (Figure 6a) were obtained using a fast spin echo pulse sequence with these imaging parameters: 256×256, 8cm FOV, a slice thickness of 3mm, TR/TE of 4000ms/95ms, echo train length of 16, 4 NEX, scan time of 4:16 minutes. The sagittal images were obtained with a resolution of 512×256, 10cm FOV, a slice thickness of 3mm, TR/TE of 4000/127ms, echo train length of 16, 4 NEX, and scan time of 4:16 minutes. The SNR of the lesion on this image was around 10, which corresponds to approximately a 3-fold increase in SNR compared to the phased array breast coil of MRI Devices Corporation. With a compression level of 3cm and using 3.2cm coils, an additional 8-fold increase in SNR can be obtained.

4 DISCUSSION

In the first year of the research, we have completed specific aim 1 as we proposed. We have presented our results in the Society of Magnetic Resonance Meeting (see attached abstract). As a deviation from the original proposal, we concentrated only on the RF receiver coil. In the original proposal a Maxwell pair was proposed for the z-gradient. Since then we have received a 3-axis echo planar gradient upgrade. This allows us to image thin slices with 100μm or better resolution. Even with the smallest coil that we designed (3.2cm diameter) the resolution is limited by the RF coil but not by the gradient strength.

In the next year of the project, we will concentrate on patient studies. We are begun to collaborate with Dr. Rachel Brem, who is recruiting patients with known lesions who are scheduled for a biopsy.

Development of different sizes of coils and configurations will continue. The frames for 2,4, 6, and 8cm coil pairs have already been built. Based on clinical experiences we will modify the design of the frame accordingly.

5 CONCLUSION

We have developed a 2-channel phased array RF receiver coil system for very high resolution MR imaging of breast lesions. Using this system, a pair of small size surface coils can be placed very close to the breast lesion and images of the lesion with a resolution of 100μm were obtained. This may enable the study of breast lesion characteristics, such as capillary density and ductal architecture. We are continuing thecnical development and clinical trials of our breast imaging system.

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1. Kaiser W, Zeitler E. "NMR tomography of the breast: diagnosis, differential diagnosis, problems and possible solutions," *Fortschr Geb Rontgenstr Nuklearmed* 144, 572-579, 1986

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3. Schenck JF, Hart HR Jr, Foster RH, Edelstein WA, Hussain MA, "High resolution magnetic resonance imaging using surface coils," *Magnetic Resonance Annual* 132-160, 1986.

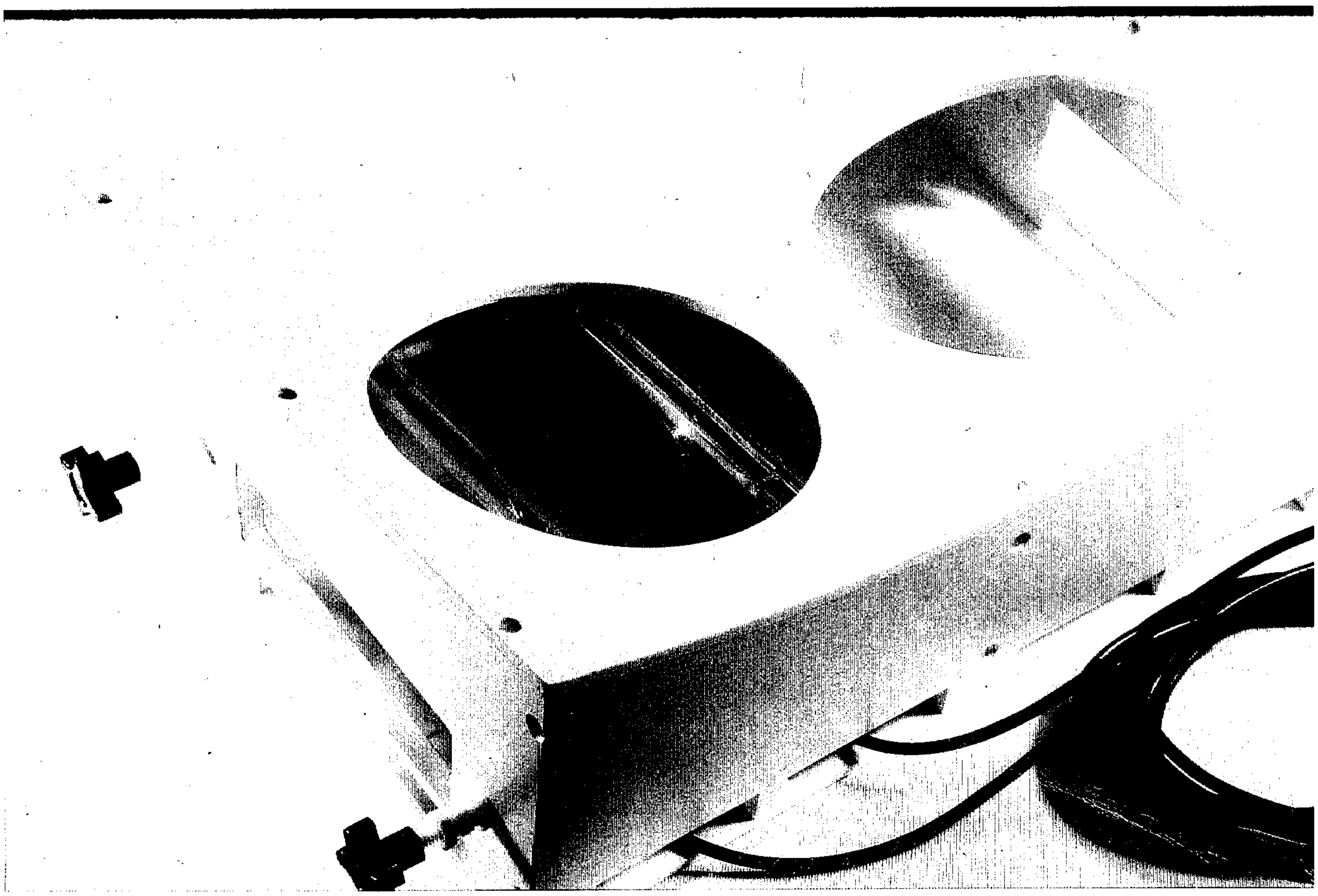

Figure 4: A photograph of the dual phased array breast coil system built in house.

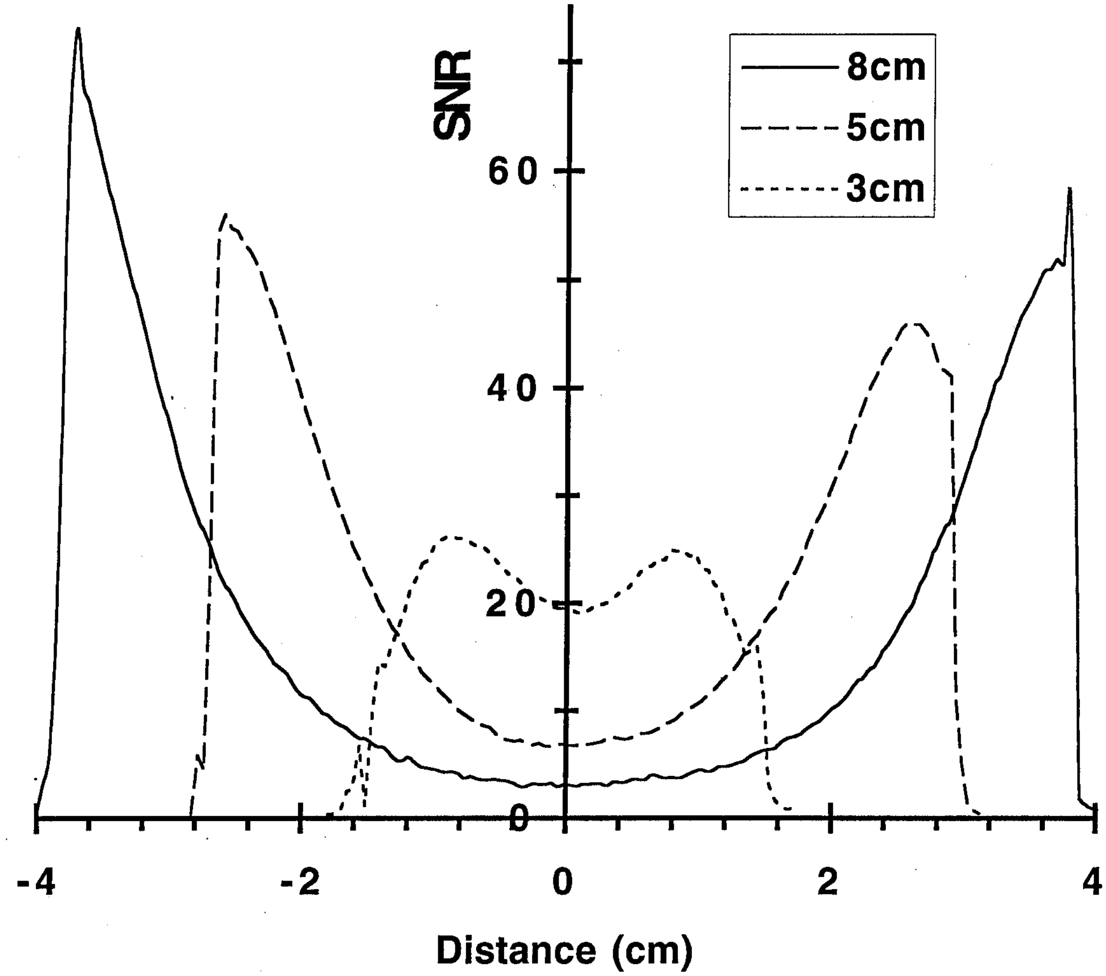

Figure 5: Plots of SNR along the axis of a 3.2cm diameter coil pair for various separations of coils as indicated on the legends of the graph. Saline solutions were imaged with a fast spin echo sequence with a bandwidth of 16kHz, TR/TE of 1500/17ms, 3mm thickness and 16 echo train length, 512×512 with 10cm FOV. The SNR was corrected for a field of view of 5cm.

Figure 6: Sample images acquired using the dual phased array breast coil system. The images are magnified by a factor of 1.5. Although the lesion was deep inside the breast, and the amount of compression and coil size was not optimal, high resolution images of the lesion were obtained.

A Phased Array Coil for In-Vivo Microscopic MR Imaging of Breast Lesions

Ergin Atalar, Ph.D. and Elias A. Zerhouni, M.D.

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Introduction

Imaging with low dose film-screen mammography is the currently recommended method of choice for the early detection of nonpalpable breast cancer in women over age 40.

Despite the high sensitivity of mammography, up to 9% of palpable cancers show no corresponding imaging abnormalities. Furthermore, with mammography, small cancers are often obscured by dense fibroglandular tissue. Another major limitation of mammography is lack of specificity which has led to a marked increase in the number of surgical excisions for benign disease.

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Method

Desired image resolution can only be achieved with a significant improvement in signal to noise ratio (SNR). This improvement can be obtained by combining small surface coils[3] with phased array methods. The two-channel phased array RF receiver coil system is shown in Figures 1 and 2. The breast is squeezed at the level of the suspected lesion between a pair of small size (4-8cm diameter) coils positioned as close as possible to the breast lesion. The position of the coil can be changed without moving the patient. The circuit diagram for a coil with 5cm diameter is given in Figure 3.

During the experiment, coupling between coils and a resonance frequency shift may occur but if the coils are separated enough, this effect and related signal loss are negligible.

Experiments and Results

Each coil is independently tuned to 63.86 Mhz and matched to 50Ω. The loaded Q of this coil was measured as 44.

For the 5cm-coil pair, we calculated the minimum distance based on Q factor and inductance of the coil. By measurements, it was verified that if the coils are separated more than 6cm, the resonance frequency shift is negligible.

Healthy volunteers were imaged by the new breast coil system, and a GE Signa 5.2 scanner with SR-230 3-axis EPI gradient upgrade. Using a fat suppressed fast spin echo pulse sequence, 512×512 images with a FOV of 5cm, a slice thickness of 3mm, TR/TE of 3000ms/50ms, echo train length of 16, 4 NEX were obtained in 7 minutes. SNR of the images was approximately 10 with 5cm coils with 6cm coil separation. Because of very high resolution, it was possible to visualize ductal structures.

Conclusion

We have developed a 2-channel phased array RF receiver coil system for microscopic MR imaging of breast lesions. Using this system, a pair of 4-8cm diameter coils can be placed very close to the breast lesion and lesion characteristics such as capillary density and ductal architecture may be studied.

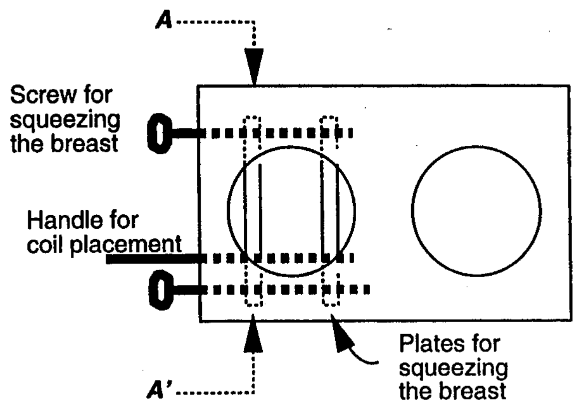

Figure 1: The top view of the breast MR microscopy system.

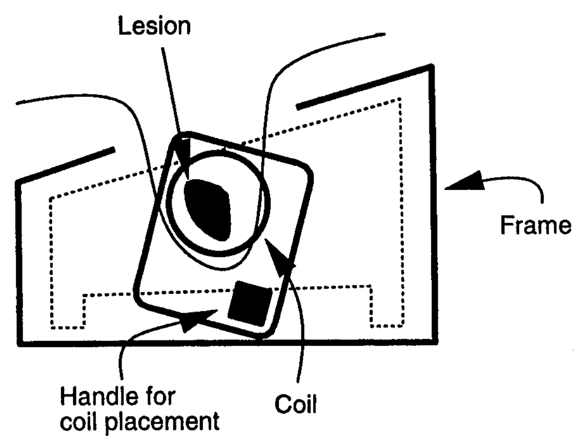

Figure 2: The A-A' section of the breast MR microscopy system.

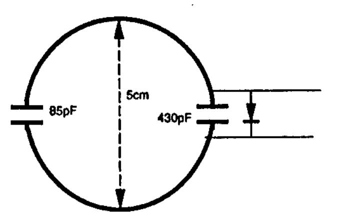

Figure 3: The circuit diagram for each of 5cm coils.

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